An Overview of Government and Industry Initiatives to Reduce Costs in Military Aircraft Design and Production

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How We'll Address the Topic Today

- Overview of project and methodologies
- Acquisition Reform findings
- Lean Manufacturing findings
- Advanced materials and manufacturing process findings

Project Structure

SPONSOR: Assistant Secretary of the Air Force

(Acquisition), SAF/AQ

MONITOR: Jay Jordan, AFCAA Technical Director

INITIATED: January 1998

END: June 2002 (Phase II Tasks)

Part of RAND Project AIR FORCE, a Federally Funded Research and Development Center (FFRDC)

- Natalie Crawford, VP and Director of PAF
- Bob Roll, Director of Resource Management Program

Objectives of the Project

- Use historical data and current engineering and management estimates to improve cost estimates
- Address development, production, operations and support, and future upgrade costs

Project Tasks

- ü Assess the effects of advanced airframe materials on manufacturing costs
- Update airframe cost estimating relationships (CERs) with the latest data
- **ü** Assess the impacts of Acquisition Reform on aircraft development and manufacturing costs
- ü Assess the impacts of Lean Manufacturing on aircraft development and manufacturing costs
- Review Operations and Support costs and develop better methodologies
- Update/develop new methodologies for estimating Avionics,
 Software, Propulsion, and Other Subsystems costs

Study Methodologies

- Visits to relevant government offices
- Questionnaires sent to participating companies
- 2-3 day company visits
- Follow-up questions and data requests
- Debriefs with participants

Government Contacts

(1998 - 1999)

- JSF, B-2, F-22 Program Offices
- AFCAA/NCCA
- OSD PA&E
- AF Research Lab (Materials & ManTech)
- NAVAIR
- NASA Langley Research Center
- Oak Ridge National Laboratory
- SAF/AQF
- Army MANPRINT office
- UK MOD / DERA
- GE MOD
- NATO-Euro Tornado Management Agency (NETMA)

Airframe Prime Contractor Participants

(1998 - 1999)

- Boeing
 - Seattle
 - St. Louis
 - Philadelphia
 - Long Beach
- Lockheed Martin
 - Ft. Worth
 - Marietta
 - Skunk Works
- Raytheon Aircraft

- Northrop Grumman
 - El Segundo
 - Ft. Worth
- Sikorsky
- Bell Helicopter Textron

Other Industry Airframe Participants

(1998 - 1999)

Composites

- Alliant TechSystems
- Cytec Fiberite
- GKN Westland Aerospace
- Hexcel
- Scaled Composites

Metals

- Kurt Manufacturing
- Precision Castparts
- Remmele Engineering

Avionics/Acquisition Reform Contractors & Government Sites Visited (1998 - 1999)

- JSF Lockheed Martin Team
- NG, El Segundo
- LMTAS, Ft. Worth
- NG-ESSS, Baltimore
- LM Tactical Defense Systems, Eagan
- LM Electronics & Missiles, Orlando
- Sanders, Nashua
- Other Contractors
 - TRW Automotive Electronics, Marshall
 - Several Focal Plane Array Suppliers

Note: COSSI is Commercial O&S Cost Savings Initiative

- JSF Boeing Team
 - · Boeing, Seattle
 - Raytheon, El Segundo
 - Raytheon, Dallas (Formerly TI)
 - Raytheon Plano (Formerly TI)
 - TRW Avionics, San Diego
 - Sanders (at Boeing, Seattle)
- Government Sites
 - F-22 SPO
 - F-18 PMA
 - DoD COSSI Program at ASC
 - AFRL IBP MANTECH Program w/TRW
 - AFRL Sensors Directorate, Dayton LAWS, IDA & ERASER
 - NAWC, Pax River DAIRS, MIDAS

"An Overview of Acquisition Reform Cost Savings Estimates"

Dr. Mark Lorell, Author

What I'll Talk About

- Project objective
- History of AR
- Taxonomy of AR measures
 - Regulatory initiatives and savings
 - Commercial-like program initiatives and savings
 - Multi-year savings
- Findings/Rules of Thumb

AR Task Research Objective

- Assess likely range of cost savings from Acquisition Reform (AR) for R&D and production of future combat aircraft
 - Collect and assess published studies on AR cost savings
 - Collect quantitative and qualitative data from aerospace contractors

Acquisition Reform Chronology

•Mid-1980s Early 1990s	Many studies of DoD cost premium
•Fall, 1989	Sect. 800 of FY 90 Nat'l Defense Authorization
•1992	National Performance Review
•1994	Sec'y Perry's "Acq Reform - Mandate for Change" & "Specifications and Standards - A New Way of Doing Business"
•1994	Dep Asst Sec'y for AR appointed; PAT established
•1994	Federal Acquisition Streamlining Act
•1994	Coopers & Lybrand Report on DoD cost premium
•1996	Federal Acquisition Reform Act

Most Early Studies Estimate High DoD Regulatory Compliance Cost Premium

STUDY	DATE	ESTIMATED DOD PREMIUM/ COST SAVINGS
HONEYWELL defense acquisition study (20 programs, contractor costs)	1986	13%
RAND OSD regulatory cost study (total program costs)	1988	5-10%
OTA Industrial base study (total DoD acquisition budget)	1989	10-50%
CSIS CMI study (cost premium on identical items)	1991	30%
CARNEGIE Commission (total DoD acquisition budget)	1992	40%
ADPA Cost premium study (product costs)	1992	30-50%

Most use qualitative or theoretical analysis, limited data

Data-Based Estimates of the DoD Regulatory and Oversight Cost Premium

Study or Program and Date	C&L Top 10 Cost Drivers	C&L Top 24 Cost Drivers	Overall Cost Premium or Savings Potential	Estimate Quality
C&L (94)	8.5%	13.4%	18%	Limited Data
NORCOM (94)			27%	Limited Data
DoD Reg Cost Prem WG (94)		6.3%		Data & Analysis
DoD Reinvent Lab (94)	1.2%-6.1%			Data
SPI (95)			0.5%	Limited Data

Program Estimates of the DoD Regulatory and Oversight Cost Premium

Study or Program and Date	C&L Top 10 Cost Drivers	C&L Top 24 Cost Drivers	Overall Cost Premium or Savings Potential	Estimate Quality
FSCATT (95)			2%	Analysis
WCMD (96) (CDRLs only)			3.5% (R&D)	Data
B-2 Upgrade (CDRLs only)			2.3%	Data

Summary of Initial Assessments of Overall DoD Acquisition Reform Savings

Study and date	FY95-FY01	1996	FY95-FY02	Est Quality
RAND (96)	4.4%			Data
MIT (97) (av. of 23 MDAPS)		4.3%		Data
GAO (97) (av. of 33 MDAPs)			-2%	Data
GAO (97) (av. of 10 MDAPs with cost savings)			4%	Data

Regulatory & Oversight Compliance Cost Reduction

Issues:

- Separating AR initiatives versus other cost reduction initiatives
 - RAND focused on gov't to gov't and gov't to prime relationships
- Good news travels fast; bad news never gets mentioned
- Measuring real savings in a dynamic environment is challenging
 - Most activities are in overhead, costs of compliance not tracked well
- Waiving versus repealing regulations; substitutions with other "procedures"
- Everyone is skeptical of claims

R&O areas receiving a lot of attention:

- Mil specifications/standards (Mil-Q-9858A quality control)
- Cost/schedule accounting & reporting
- Single process initiative
- Truth in Negotiations Act requirements
- Government materials/property management reform

Commercial-like Practices

• Issues:

- Can "government" and defense industry act like commercial industry?
 - Government agencies not all monolithic in orientation
 - Old habits die slowly in defense industry
- Commercial parts and practices implementation varies by system and sub-system

• Commercial-like practices:

- Cost as an Independent Variable and requirements reform
- Contractor configuration control
- AUPPR/PCCs
- Commercial-off-the-shelf parts insertion
- Military production on commercial lines (dual use)
- Electronic commerce
- Contractor total system performance responsibility

Multi-Year Procurement Savings

• Issues:

- No "actuals" for path not taken
- Savings become a <u>fait accompli</u> since the money is taken from the program budget
- Hurdle rate has varied over time
- Not a new concept

Reported/Estimated Multi-Year Procurement Savings

• F-16 (FY 82-85)	10.0 %
• F-16 (FY 86-89)	10.0 %
• F-16 (FY 90-93)	5.5 %
• F-16 (FY 99-02)	5.4 % (proposed)
 Comm. Derivative Engine (CDE) 	
for C-17 (FY 97-03)	8.2 %
 C-17 (airframe) (FY 97-03) 	5.5 %*
 Javelin ATGM (FY98-00) 	14.3 % (proposed)
 Med Tactical Veh Repl 	7.4 %
 USN CH-60 (add in FY 00) 	5.5 %
• DDG-51 (FY 98-01)	9.0 %
• F/A-18 E/F (FY 00-04)	7.4 %*

^{*} Includes government cost reduction funding

Implementation of AR in Aerospace Industry

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•SPI

•CAIV

Cont. config control

•Mil specs/stds reform

Commercial-like contracting

Dual use of production

Use of COTS

•Electronic commerce

Reduced reporting/data

DoD Implementation/savings

Wide, small savings

Partial (esp. pilot programs), varies

Wide, but shallow implementation

Wide (replaced by ISO), some (see

COTS, dual use)

Partial (pilot programs, OTA,

COSSI), insuff data, potentially large

Little (pilot programs), Insuff data,

potentially large (electronics, IT)

Partial, uneven, some (potentially large

in electronics, IT)

Wide, some

Wide, small

AR Bottomlines

- Reducing DoD regulatory/oversight compliance burden results in modest savings of ~3-4%, not 20%
- Significant savings may be achievable through more radical programmatic/structural AR reforms (commercial, CAIV), but
- These have not been widely applied outside of AR demonstration programs
- Many demos characterized by low technological risk, commercial derivative items, large production runs
- Scale of potential cost benefits for high risk cutting edge technology programs still uncertain
- •Multi-year savings of 5% feasible, but flow down to subcontractors needs to be assessed carefully vs. lean strategic supplier relationships

AR Rules of Thumb for Cost Estimators

- If comparing a pre-AR program (~1994) to a new program, reductions for regulatory burden of 3-4% are reasonable at the program acquisition level
- If using prior program(s) direct costs (labor hours), negotiated Forward Pricing Rate Agreements (wrap rates) probably contain AR reform reductions already
- AR reductions between supplier and prime may have to be assessed separately
- •Commercial-military integration needs to be assessed as appropriate, probably at purchased materials level
- •If separate, new AR initiatives are identified, evaluate separately and apply to baseline cost estimate
- •Multi-year savings of ~5% in production are reasonable, but may have to be evaluated against strategic supplier relationships

"Military Airframe Production Costs: The Effect of Lean Manufacturing"

Dr. Cynthia Cook

Overview of Lean in Aerospace Industry

- Definition and history of Lean Manufacturing
- Lean design
- Lean manufacturing
- Lean procurement
- Conclusions/implementation

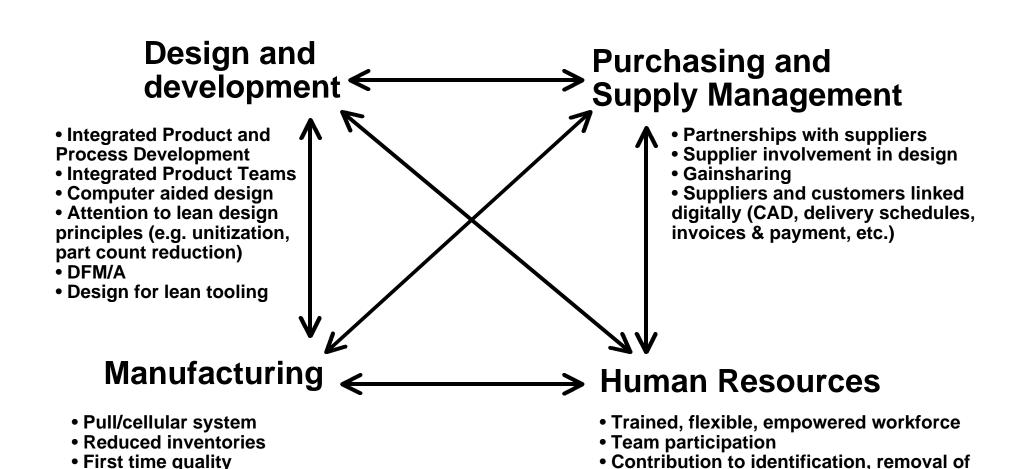
What is Lean Manufacturing?

- •A systematic approach to analyzing and removing sources of inefficiency and waste in production
- •An enterprise-wide (company, supplier and customer), communication-intensive view of the production process
- •A long list of tools, new practices, and innovative processes that contribute to the removal of excesses
- •Synergistic improvement of all processes in the value stream
- •RAND focus was on prime processes and prime-subcontractorsupplier relationships

Lean Promises Significant Improvements in Manufacturing

- Production system originally developed in post-War Japan at Toyota as a response to shortages
- •Publicized in West with MIT International Motor Vehicle Project (IMVP) report *The Machine that Changed the World* (Womack, Jones & Roos,1990)
- Claims include
 - 1/2 human effort in factory
 - 1/2 manufacturing space
 - 1/2 investment tools
 - 1/2 engineering hours
 - 1/2 time to develop new products

Lean is an Enterprise Approach; Linked Functions Affect One Another



Continuous improvement

costs, quality problems

Lean Design and Development

- •Goal is to quickly develop manufacturable product, with a good design that appeals to customers
- •DoD-directed IPT structure attempts to incorporate inputs of all stakeholders into process, may require increased resources (+10 to 20% of EMD workyears) up front
- •Attention paid to ease of manufacturing puts focus on standardized parts, reduced part count (unitization), manufacturing product flow, tooling reduction, etc.
- •Programs using IPTs (along with computer aided design tools) reported better first-time fit-up

Effect of Digital Technology on Design

- Computer technology enables improvements
 - 3D solids currently state of the art in aerospace; make design analysis and drafting tasks much easier
 - engineers suggest tools used to create better designed airplane with same level of effort, rather than same airplane with reduced level of effort
 - can analyze tooling concept to ensure manufacturability
- Computer technology contributes to better fit, ease of manufacture
 - programs using tools reported near perfect first-time fit-up
 - should lead to lower T1s and reduction in rework costs

Many Contrasts Between Traditional Manufacturing and "Lean" Factory

Traditional Manufacturing

- •Tools organized by process ("process villages")
- Large batches, long set-up times
- Push system
- •Inventory acts as a buffer
- Parts inspected for quality
- •Centralized tool cribs, disorganized parts bins

Lean Factory

- Tools organized by product cellular flow
- •Low batch sizes, set-up times reduced
- Pull system
- Low/no inventory
- •Processes inspected for quality, Six Sigma, SPC, 5Ss, TPM, visual controls
- Kitting of parts and tools
- •Focus on continuous improvement, kaizen events

Reported Savings from Lean Factory Pilots Data collected in 1998 as part of RAND study

- •All companies had pilot projects, with initial evidence of savings
- •Small pilots reduced labor costs up to 2/3, larger efforts had smaller average payoffs (most between 15-25%, some outliers)
- •Cycle time to produce part reduced from 13% 93% (average 44%)
- •Floor space savings 0% 61% (average 24%). Part travel savings from 25% 95% (average 61%) People travel reduced 23% 94% (average 55%)
- Complete scope of savings difficult to assess from available data
 - no evidence of complete transition to lean

Lean Inventory

- Savings enabled by pull system, JIT delivery, EDI with suppliers, kitting, etc.
- Direct cost savings from decreased inventory
 - lower carrying costs (inventory turns increase 1 3.5 x; WIP down 10% in first year, 50% in long term)
 - fewer people to manage inventory
 - reduced space requirements
 - reduced scrap from expired perishables (e.g. epoxy)
- Indirect cost savings from reduced inventory
 - forces manufacturing to adopt first-time quality initiatives
 - fewer QAs, lower scrap, increased operator self-inspection

Lean Purchasing and Supplier Management

- •Lean supplier management a philosophical shift from traditional "arms-length" contract relations
- •Rationalization of supply base across enterprise allows focused attention on partner suppliers
- •Trusting relationships allows for asset-specific investments without threat of hold-ups
- •"Target pricing" means flow-down of price targets for suppliers
- •Investments in improvements on both sides enable shared savings
- •Electronic linkages facilitate shared information

Many Contrasts Between Traditional and Lean Procurement

Traditional Procurement

- •Arms-length relationships, low commitment
- •Win-lose philosophy, no gainsharing
- Many suppliers
- Outsourcing of individual parts assembled at prime contractor
- •Little communication, little information shared

Lean Procurement

- Closer relationships, long-term commitment, mutual assistance
- Gainsharing, win-win philosophy
- Fewer suppliers, tiered structure
- Outsourcing of subassemblies; parts produced at lower tiers, assembled at upper tiers
- Intensive communication, much information shared, IPT participation
- Joint search for cost drivers at suppliers

More Contrasts Between Traditional and Lean Procurement

Traditional Procurement

- •Parts delivered in large batches to customers loading dock, then moved to inventory storage
- •Parts inspected upon arrival at customer
- Supplier "builds-to-print" based on detailed specs

Lean Procurement

- •Just-in-time (JIT) delivery of small batches direct to factory floor enables cellular manufacturing/one piece flow
- Processes inspected at supplier
- •Supplier participates in design process (IPTs), designs own part to fit requirement, linked to project CAD system

Savings from Lean Purchasing

- Materiel largest part of cost structure of aircraft
 - **45% 65%**
- •Estimates on possible savings range from conservative 4% or 5% (based on experience and projection) to aggressive 20% (unproven estimate)
 - savings should be captured in cost of materials
 - 4 to 5% savings similar to best commercial firms
- •Other savings from fewer people in procurement, fewer suppliers to manage, reduced paperwork, resulting in lower FPRA/material handling fees

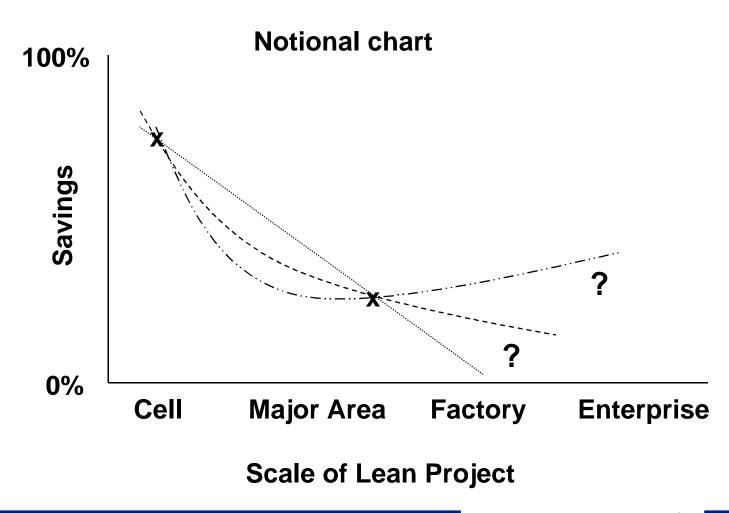
General Findings From Site Visits

- Lean implementation varies across firms, and across different locations within same firm
 - many pilot programs show efforts are being made; how to scale-up credit across enterprise?
- Evidence from airframe manufacturers shows incomplete shift to lean manufacturing
 - question of total savings from lean enterprise can't be answered yet
 - lean synergism: must whole enterprise be lean for savings?
- Firms provided qualitative explanations of lean efforts; very little proven quantitative data offered

Summary Affect of Lean by CCDR Category

- Design and Development: IPTs a cost driver, may increase costs 10-20%. 3D design tools used to make better design, rather than same design more quickly.
- Tooling: Costs reduced through flexible tooling, self-locating parts, etc. Managing flow decreases required # of rate tools.
- Quality: Cost of quality should decrease, but data not yet available due to limited implementation.
- Direct Manufacturing: May save 10-20% or more in direct labor. "Cellular" pilots limit assessment of scaled-up implementation.
- Materials: 5% savings in cost of purchases possible with significant effort. Can also improve quality, delivery with careful management of suppliers. Reduced inventory should decrease material overhead.
- Overhead: Least data here. ERP may enable savings.

Slope of Savings Curve From Lean Implementation Not Known



Quotes from Dr. Gansler Presentation at LAI Executive Board Meeting, May 1999

- •I had hoped that, with five years of "lean" research under your belt, we would have begun to see some significant impact on the "top lines" of our defense programs, i.e. the overall costs and schedules for weapons systems.
- •I am sure you agree that your successes in specific elements of the production process must be extended and accelerated to all our programs and -- most important -- that we begin to see quantifiable data demonstrating the benefits of the "lean" approach at the weapon system level. So far, we just haven't been able to produce such data.

Best Practice/Lean Manufacturing is a Moving Target

- •Best practices in industry evolving at a rapid pace, original RAND study conducted on 1998 data
- •Further research in support of AFCAA PCRP review of the F-22 demonstrates more data now available
- •Full effect on acquisition costs not yet known further study required. Data should demonstrate
 - reduction in standard hours/actual hours/ materials in total part/process/product
 - reduction in total cycle time
 - freed-up workers can move to other work
 - reduction in total overhead costs
 - evidence of reduced costs in total value stream.

Conclusions

- Lean manufacturing may offer DoD savings over what historical production models would predict
- •Not enough credible evidence exists now to confidently quantify the savings; therefore, it is premature now to adjust overall CERs for lean savings. Instead, lean credit should be taken on a caseby-case basis for demonstrated improvements (i.e. F-22 PCRPs)
- •DoD should take role of active customer, know current best practices, judge and reward contractor for ongoing lean activities and continuous improvement

"Military Airframe Costs: The Effects of Advanced Materials and Manufacturing Processes"

Obaid Younossi

Overview of Advanced Materials and New Manufacturing Processes in the Aerospace Industry

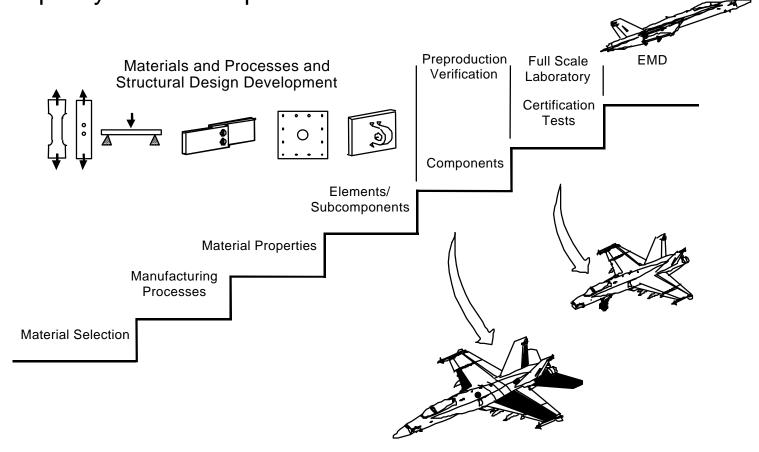
- Design considerations for modern manufacturing
- New manufacturing processes
 - Composites
 - Metals
- Applying new initiatives to aircraft cost estimates
- Future projections for advanced materials costs
- Bottom lines for cost estimators

Design Considerations

Use of Qualified Materials and Processes Reduces Development Effort

Material qualification

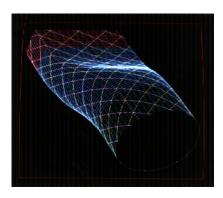
 A building block approach to generate design allowables and qualify fabrication processes



Computer Aided Design Tools Lead to Producible Designs But ...

CAD / CAM

- Design tools should produce better designs with lower production costs, but not necessarily fewer design hours
 - Additional design iterations
 - Integrates design, manufacturing, and maintenance databases
- Reduces the need for mock-ups



Models 3-D surface and calculates 3-D fiber paths



Simulates material laydown and manufacturing times

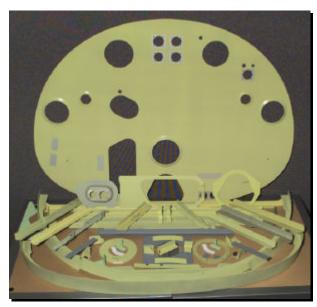


Calculates machine instructions for fiber placement

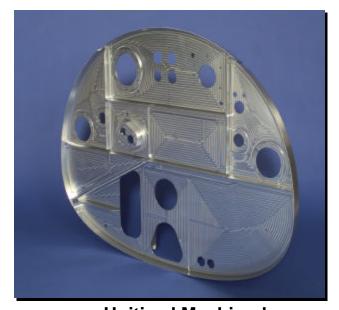
Unitization Reduces Part Count Assembly Time but ... More Complex Parts

Metals and Composites Unitization

- Reduces part count
- Reduces number of fasteners
- Reduces assembly time
- Leads to more complex parts to design, fabricate, repair, and maintain



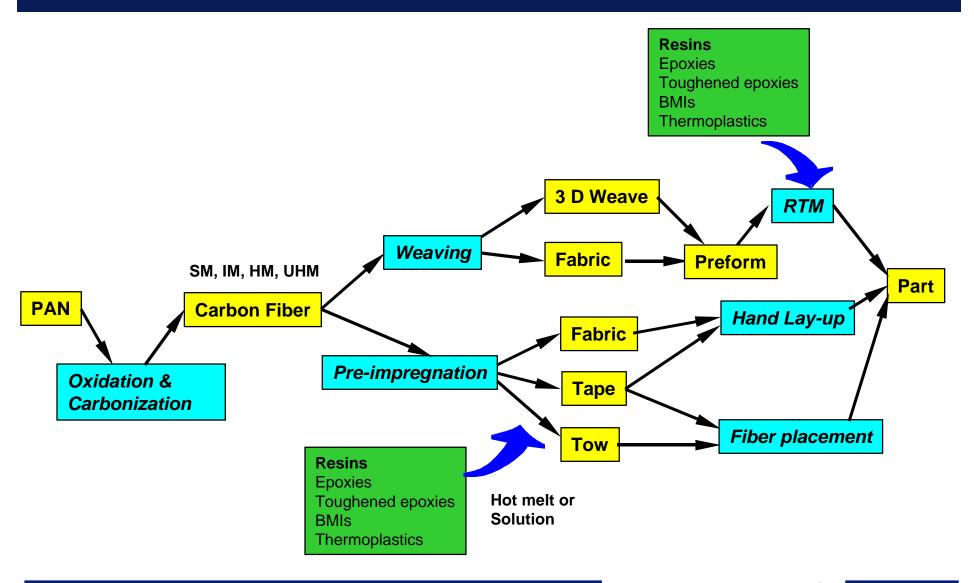
Sheet Metal Built-Up



Unitized Machined RAND Project AIR FORCE

Manufacturing Processes

Composite Part Production Cycle



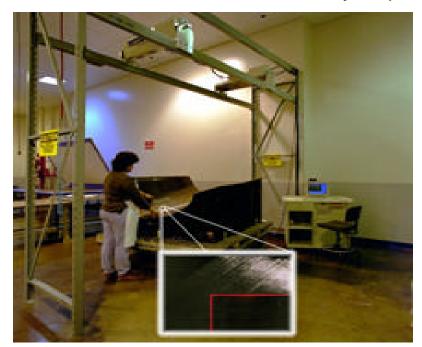
Use of Optical Laser Ply Alignment Reduces Cost

- Composite fabric or tape is layed on a solid tool by hand, either using Mylar templates or following a laser projection pattern. This is the most common process used in the aerospace industry.
 - This process can be used to fabricate a variety of parts

Capital Cost (FY00\$):

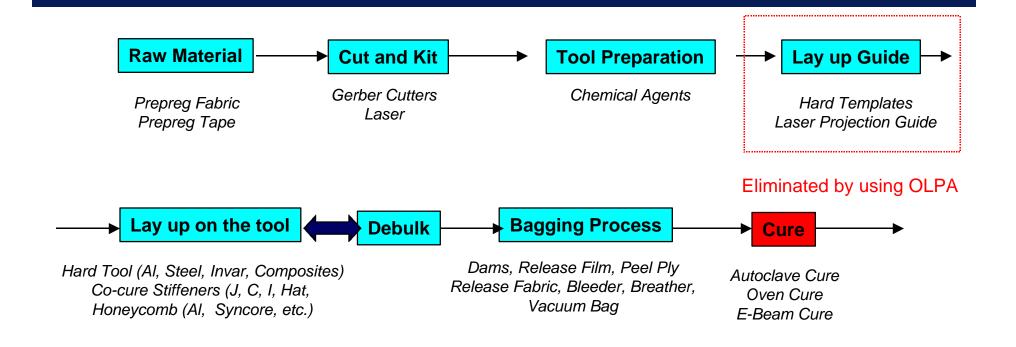
Automatic cutters - 1-7 M Autoclave - 0.25-4 M OLPA - 50 K

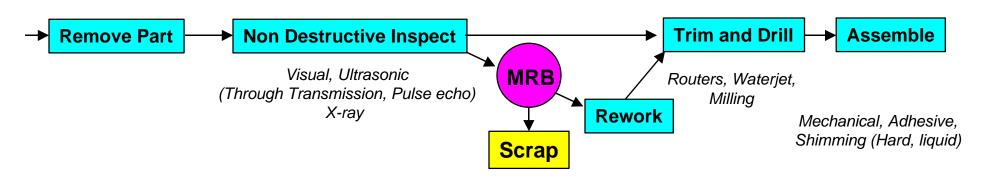
BTF - 2.5 - 1.9 Fabrication Slope - 86%



OLPA should lead to a 10-15% saving in fabrication and a 15% saving recurring tooling cost

OLPA Eliminates a Time Consuming Step





Automated Tape Placement Saves Production Labor for Complex Composites Shapes

- •Is the automated mechanical means by which the fibers (tape or tow) are placed on a tool in their proper position.
 - This process is most suitable for complex contour shapes

Capital Cost (FY00\$):

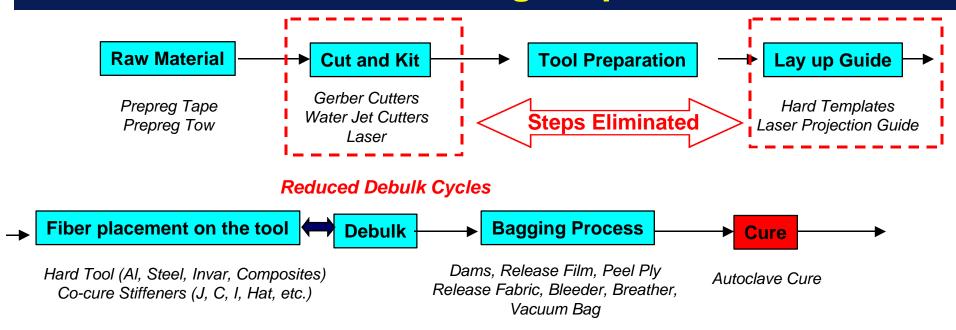
Fiber placement machine 2 - 6 M

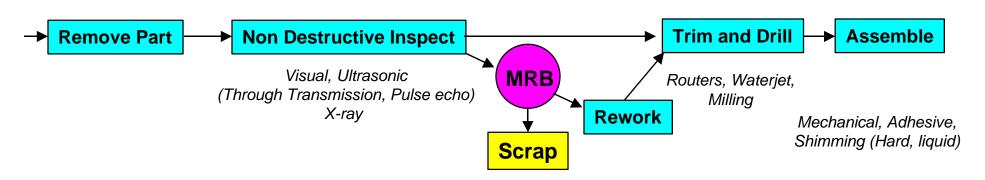
BTF - 1.5 - 1.3 Fabrication Slope - 90%



Fiber placement should lead to a 10 - 35 % saving in fabrication labor and improved BTF

Automated Tape Placement Eliminates Time Consuming Steps





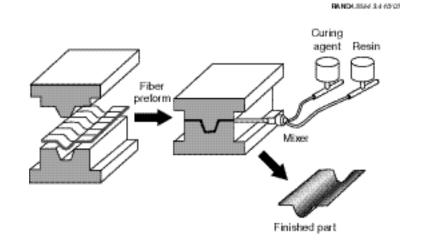
Resin Transfer Molding (RTM) is Most Suitable for Complex and Very Complex Shape

Accomplished through injecting catalyzed resin into a fiber preform.
 This process uses closed tools and the resulting part has well defined outside surfaces and much more dimensional stability.

Capital Cost (FY00\$):

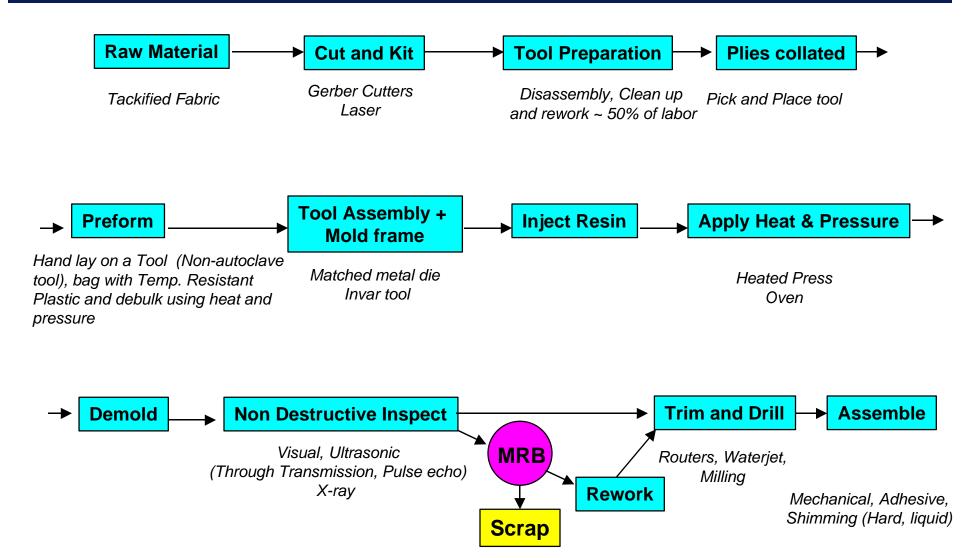
Automatic cutters - 1-7 M RTM Oven - 6 - 280 K RTM Press - 1 - 3 M

BTF - 2.5 - 1.9 Fabrication Slope - 90%



RTM should lead to a 10 - 25 % saving in fabrication labor for complex and very complex parts over a long production run

Composite Manufacturing Process Flow (Resin Transfer Molding)



Metallic Materials

Aluminum

- Conventional aluminum historically well understood design characterization
- Used in light weight low strength applications
- Newer aluminum lithium alloys show higher strength and better processing properties

Titanium

- Making a comeback well understood design characterization
- Used in <u>higher strength and high temperature</u> applications
- Mechanical properties compatible with composites

Steel

- Limited applications in airframes
- Used in very high strength situations such as landing gear

Unitization Takes Advantage of High Speed Machining

 Capable of high volume metal removal, while reducing machining forces and power absorption, as well as shifting the heat from the work piece to the chips

Capital Cost (FY00\$):

HSM machine - 2 - 4 M

BTF - 16 - 20 Fabrication Slope - 86%



HSM should lead to a 15 - 35 % saving in aluminum and up to 15% saving in titanium fabrication labor - Shift from castings and forgings into machined parts

What if We Manufactured Yesterday's Aircraft Today?

Then

- Most aluminum and titanium fabricated using conventional machining
- Fuselage, empennage and substructure composites fabricated using hand lay-up method only
- Traditional assembly techniques

Now

- Most aluminum and titanium fabrication accomplished using high speed / performance machining
- Fuselage, empennage and substructure composites fabricated using optical laser ply alignment system plus some automation
- Wing skins fiber placed using automated means.
- Modern methods of assembly employed

An Example: Typical Airframe Material Distribution and Complexity Assumptions

Airframe Structure Materials Composition

	Aluminum	Steel	Titanium	Composite	Other	Total
Fuselage	33%	9%	3%	4%	12%	61%
Wing	6%	1%	3%	17%	4%	31%
Empennage	2%			4%	1%	7%
Other	1%					1%
Total	41%	10%	6%	25%	17%	100%

Airframe Structure Complexity Assumptions

	Aluminum	Steel	Titanium	Composite
	Medium &	Medium &	Medium &	
Fuselage	Complex	Complex	Complex	Medium
	Medium &	Medium &		Simple &
Wing	Complex	Complex	Medium	Complex
	Medium &			
Empennage	Complex		Medium	Medium
	Medium &			
Other	Complex	Complex		Medium

Modern Methods Would Lead to 15 - 20 % Less Manufacturing Hours

Aircraft

Past Technology

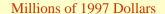
Future Technology

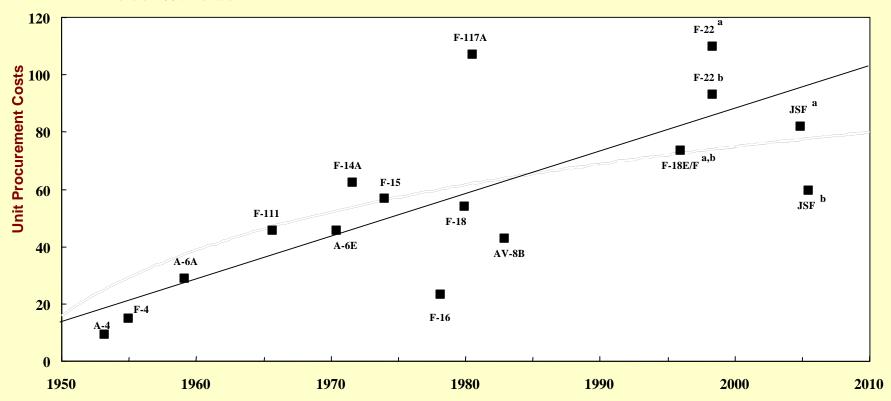
Adjustment Factor

1.33

1.07

Aircraft Unit Cost is Increasing due to Increased Complexity





SOURCE: Congressional Budget Office, A Look at Tomorrow's Tactical Air Force, January 1997

NOTE: The line is a linear regression of the historical aircraft cost.

- a. CBO estimates
- b. Administration estimates

Future Projections for Advanced Materials

Composites

- Specialized fabrication techniques
 - Vacuum Assisted Resin Transfer Molding, Stitched Resin Film Infusion, out of autoclave curing - E-Beam, etc.
- New or improved material systems
- Advanced assembly techniques
- State of the art quality control techniques Laser UT

Metals

- HIP casting, laser forming, and high performance machining of titanium
- Improved aluminum-lithium alloy

New processing techniques have the potential for reducing tooling costs, manufacturing labor, and material costs

Bottom Lines for Cost Estimators

- Use of advanced materials and composites in aircraft is increasing
- New manufacturing processes and materials have made production less expensive, but unit cost of aircraft airframes is increasing because they are more complex
 - New design tools lead to a more producible and supportable designs, but not necessarily a reduction in design hours/cycle time
 - New manufacturing techniques should reduce labor hours, improve quality, and flat improvement curves
- Yesterday's aircraft made with today's techniques would have 15-20% less manufacturing hours